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ABSTRACT

For the individual, gender difference falls along the feminine-masculine continuum with strong neurodevelopmental influences at various points throughout the lifespan. Neurodevelopmental influences are conceptualized in a vector model of sex difference. Vector attributes, direction and magnitude, are influenced initially by differences in levels of sex hormones at developmentally sensitive points in the lifespan. Hormonally induced variation is secondarily reinforced by sex role influences of society and culture. A hormonally induced and culturally reinforced vector model of sex differences is adequate to account for the large range of variation in cognitive and learning patterns of individuals within female and male populations, as well as the mean difference between the gender groups. (Author)

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SEX DIFFERENCES AND NEURODEVELOPMENTAL VARIABLES: A VECTOR MODEL

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ABSTRACT

For the individual, gender difference falls along the feminine-masculine continuum with strong neurodevelopmental influences at various points throughout the lifespan. Neurodevelopmental influences are conceptualized in a vector model of sex difference. Vector attributes, direction and magnitude, are influenced initially by differences in levels of sex hormones at developmentally sensitive points in the lifespan. Hormonally induced variation is secondarily reinforced by sex role influences of society and culture. A hormonally induced and culturally reinforced vector model of sex differences is adequate to account for the large range of variation in cognitive and learning patterns of individuals within female and male populations, as well as the mean difference between the gender groups.

A Perspective on Sex Difference

A major source of controversy in sex difference research is whether evidence of differences associated with gender may be inappropriately applied to reinforce sex stereotyping. Is it possible to deal effectively with such perplexing, multifactored and emotionally charged issues?

A vector model of sex difference that focuses on differences between individual members of the female and male gender groups and the sex related changes that may occur during development of the individual may be useful to effectively defuse sex difference controversy. In most of the literature on gender difference, human females and males are typically considered to be discrete groups; in reality, no individual is totally female or male in behavioral characteristics. Each individual falls at some point along the feminine-masculine continuum, when any of a number of crucial sex related variables are considered. The sex hormones, estrogen and testosterone, provide a good illustration of a sex related variable that influences neuropsychological function (as we shall discuss in some detail later). Estrogen, the feminizing sex hormone, and testosterone, the masculinizing sex hormone, are present during development in every individual whether that individual is female or male. The relative level of estrogen to testosterone is higher in females than in males and vice versa; but both are present and the levels of the two sex hormones vary substantively within the members of the same sex group. In addition, the level of the sex hormones fluctuates dramatically at certain points in the individual's lifespan (particularly in utero and during adolescence). Such hormonal fluctuation is associated with developmentally sensitive periods (Languis, Sanders and Tipps, 1980).

Therefore, it is appropriate to view sex difference in terms of the individual member of the gender group. This analysis must be viewed in two important ways: First, the position of the individual along the feminine-masculine continuum with respect to key sex related variables must be considered. Second, the magnitude of change in position of the individual at developmentally sensitive periods along the female - male continuum for key sex related variables must be recognized.

The vector model in mathematics provides a useful metaphor for conceptualizing human gender differences as we have just described them. In a simplified way a vector is a quantity, (e.g. a force), that has both direction and magnitude (an assigned value).

(Insert Figure 1 about here).

Any change in a vector is the result of influences acting upon it. The influences may originate internally or externally; however, the central concept is that identifiable influences are responsible for the origination of the vector quantity and for every subsequent change in vector values. Therefore, sex related variables may be viewed as providing the vector attributes (direction and magnitude) for the individual's neuropsychological function in the area of gender differences. In addition to explaining average differences between female and male gender groups, the vector model of sex differences is adequate to deal with the range of individual difference observed within a gender group, and with change in sex related attributes of individuals or gender groups over time. In addition, the model is useful for providing a means of conceptualizing gender

differences consistent with notions of individual differences in cognitive and learning style patterns in practice in the helping professions (Languis 1981b, 1983b, 1983c). The discussion which follows considers some of the key variables in the vector model of sex differences in neuropsychological function.

(Insert Figure 2 about here).

Observation of the overt behavior of females and males ranges from being remarkably similar to acutely dissimilar. Our ability to explain such observations may provide Homo Sapiens insight towards better understanding itself. A number of key variables become relevant in the investigation of male/female differences. Both similarities and differences between the sexes exist at various levels of these variables. These similarities and differencces are critical to each individual's overt behavior and provides direction to the lifelong development of sex-related variability in the neuropsychology of females and males.

Hormones

Description of sex differences in anatomic asymmetry has little meaning in isolation. However, when taken as an indicator of more meaningful functional differences, we begin to search for the underlying developmental causes. The most important and obvious variable is the genetic difference between males and females. We share an X chromosome; but how significant might the impact be of having an XX structure, versus an XY structure? Other than simply providing for genetalia, the hormone variability inherent in the structure of the sex chromosomes is most likely the critical variable in the development of functional anatomic differences, cognitive processing characteristics and overt behavioral

patterns.

The critical element impacting the variability in development has been suggested to be circulating androgens from the testes (Phoenix, Goy, Gerall and Young, 1959). Phoenix, et al. (1959) suggested that the circulating androgens are both morphogenetic and psychogenetic. Their organizational hypothesis suggests that both neural processes mediating sexual behavior and the reproductive organs innately tend towards the female pattern. However, androgens have the effect of enhancing male patterns of overt behavior and the male reproductive organs. In females, the critical element in the development of behavioral and physical characteristics seems to be the greatly reduced levels of androgens (reviewed by Goy and McEwen, 1980). Thus the Y chromosome, the obvious marker for masculinity, modifies both female structural and functional characteristics via the androgen level. The literature in sex differences in behavior consistently documents the impact on the masculinizing gender role of the androgens. Likewise, females who have been prenatally androgenized, assume some male gender role behaviors (Ehrhardt and Baker, 1974). Most common in the data are reports of behavior of females masculinized in utero by the impact of the adrenogenital syndrome (cogenital adrenal hyperplasia). Ehrhardt and Baker (1974), report that these females demonstrate higher activity levels, tomboyishness, a preference for male friends and less interest in dolls.

The significance of these data is that in utero levels of circulating androgens have tremendous impact on the developing fetus, resulting in behavioral variability. It is important to suggest that the result is not necessarily an either-or proposition, which results in the development of a normal male, feminized male, normal female or masculinized female (reviewed by Reinisch, Gandelman and Spiegel, 1979). Obviously, the interaction of variables results in

the potential for a continuum of behavioral effects. The extreme cases (i.e. adrenogenital syndrome) serve to illustrate the potential extreme result (masculinized female). However, our hypothesis suggests that the variability in levels of circulating androgens during in utero development results in a behavioral continuum upon which males and females might be placed. The literature consistently describes the following general female/male behavioral dichotomy:

FEMALE	MALE
Accommodating	Aggressive
Social	Exploratory
Verbal	Visual spatial
Compliant	Dominant

In addition, other research suggests that two female behavioral patterns are innate; sexual attraction to men and a care giving attachment to children, whereas the male has only the innate sexual attraction to the female and must learn parenting behavior from the female (c.f. Goy and McEwen, 1980). The list can obviously continue, but the point remains that the sterotypic female/male behavioral dichotomy suggests very different behavioral patterns. The argument remains as to whether behaviors are biologically controlled, culturally reinforced or perhaps an interaction of the two (Bradshaw and Nettleton, 1983). Clearly a more productive model of sex difference is needed to resolve compartmentalizing dichotomies.

Patterns and Disorders in Language and Spatial Learning

The tendency has been to oversimplify explanations of female/male behavioral dichotomies using arguments based upon the significant hormone differences in each gender group (Rogers, 1976). The hormone variable is only a portion of the picture, albeit a large part. Indirectly related to hormone variability is the development of higher cognitive abilities, such as language. The highly developed verbal ability of humans is a characteristic which makes our species unique from all others its development, which has been demonstrated to be quite different between females and males (reviewed by Bradshaw and Nettleton, 1983), is a critical component of sex differences in neuropsychological function. Development of lateralization for language processes has been suggested to be a very different process between the sexes (McGee, 1979, McGlone, 1980 and Witelson, 1976). Caution is necessary in drawing conclusions that the development of lateralizaion for language is one way for females and another for males. Although there is a more defined pattern for each sex, a continuum of developmental patterns may be appropriate, as in overt behavioral characteristics influenced by hormones. As suggested by the vector model of sex differences, individuals comprising the extremes on the continuum would be females on one end and males on the other, but the bulk of females and males may fall within a shared region. Such a concept may be represented by Figure 3:

(Insert Figure 3 about here)

In the following discussion we will contrast language ability with visuo-spatial ability and will deliberately utilize the simplistic female/male dichotomy in order to describe the extreme cases from the preceding figure.

The extreme case will again provide insight into the underlying components of the female/male differences. Developmental learning disorders (dyslexia, stuttering, etc.) provide the extreme case. Developmental learning disorders may be described as a combination of characteristics: inability to learn to read, poor auditory memory, poor spelling and delays in language acquisition. Males are much more likely to have such disorders than females, ranging from 75% to 90% of the learning disordered population, depending on the definition of the learning disorder. Research in the area has been especially fruitful over the last several years and may be useful in serving as a basis for drawing more subtle comparisons in lateral brain development and function between males and females.

Initially, rate of neural maturation was suggested as the potential source of differences in verbal and visuo-spatial skills (Waber, 1976). In the case of developmental learning disorders, excessive delay in left hemispheric development resulted in the disability. Generally, it was suggested that the overall delay in rate of maturation among males resulted in the increased likelihood for later development of lateral specialization. The same hypothesis suggested that females, due to earlier development, are more bilaterally specialized for one particular ability -- language. In addition, deLacoste-Utamsing and Holloway, (1982) report that the splenium of the female corpus callosum is larger, supporting the notion that among females there is more similarity of function left to right due to greater capacity for interhemispheric communication. Differences in cognitive ability might then be a result of very different patterns of development in cortical organization. Bradshaw and Nettleton (1983), suggest that the first stages of language development occur during a time when the left hemisphere and then the right pass through a critical state of neural plasticity. The result is expressed in females specializing in both hemispheres

for language processes. Such a process will lead to a lack of development of visuo-spatial functions more commonly reserved for the right hemisphere. The more typical male pattern of delay in maturation would lead to greater lateral specialization of function reserving the right hemisphere for visuo-spatial specialization. However, in the extreme case, there is a much increased likelihood that males will suffer from developmental learning disorders related to the delay in language specialization. The literature describing these developmental differences is extensive and suggests strong support for the developmental hypothesis (Kraft 1984; Naour, Languis and Martin, 1984; Berlin and Languis, 1980; Levy, 1976; Witelson, 1976; Harris, 1978). In a sociobiologic sense, the enhanced hemispheric lateral specialization in males may have developed to provide the development of spatial skills critical for survival in travel, hunting, and scavenging. On the other hand, female development is enhanced for functional strength in language capability, in order to carry on oral transmission of social and cultural.

Embedded within the variable of developmental delay are two important dimensions, the timing and the duration of delay. The timing and duration of the delay, provides potential for a wide range of variability in the expression of the development in right/left symmetry/asymmetry and verbal/visuo-spatial functioning. Recently, Geschwind and Behan (1982) have suggested a more inclusive hypothesis for the expression of developmental learning disorders. They propose that female and male in utero levels of testosterone, as they vary both in timing and duration are critical factors. Their research suggests relationships among a cluster of characteristics common to individuals having developmental learning disorders. The characteristics include: higher male incidence of learning disorders, higher rate of left handedness among males in general, in the left handed male population a much higher incidence of immune

system dysfunction (asthma, allergy, migraine, etc.) and abnormal development of left temporal cortex (Galaburda and Kemper, 1979). All of these factors can be explained by in utero levels of testosterone. Increased levels of testosterone in utero result in potential delay of development of the thymus gland, controlling immune regulation. Most importantly, testosterone controls neuronal migration to the cortex during the fetal development. Increased levels may result in delays of cortical cellular lamination or pathologic lamination (Gallaburda & Kemper, 1979). These researchers have described cortical abnormalities in brains of several males identified with developmental learning disabilities who have come to autopsy. Most importantly the abnormalities are limited to the left inferior temporal-parietal region and left thalamus. Geschwind (1983) suggests that the increased incidence of left handedness relates to the pathology of the left hemisphere, forcing right hemisphere dominance and resulting left handedness. Obviously, the cortical pathology in the left hemisphere language association region lead to the likelihood of developmental learning disorders. Geschwind and Behan (1982), suggest that males are more likely to manifest these characteristics because the fetal testes in utero produce testoterone at levels per unit body weight higher than during adolescence. Geschwind (1983), is also quick to point out that right hemisphere dominance in males and in non-right handed populations leads to much higher visuo-spatial ability and a resulting overrepresentation in occupations such as architecture, engineering, and athletics, in cognitive areas such as geometry and problem solving in mathematics and in visuomotor ability on the athletic field. However, learning disabilites may be a result as well, depending on the variance between timing and duration.

Additional support for the Geschwind and Behan hypothesis may emerge as contempory research in cognitive areas such as mathematics is interpreted. Sex

difference in mathematical reasoning for high ability students has been reported by Benbow and Stanley (1983). Mathematical reasoning was assessed by the mathematical portion of the College Board Scholastic Aptitude Test (SAT-M). Particularly at the levels of mathematical reasoning above 600 (maximum score possible = 800), the number of boys exceeded the number of girls by more than four to one. These data have elicited substantial controversy. Benbow and Stanley (1983) argue that hypothesized explanations of sex difference in mathematical reasoning may not be explained by differential formal training in mathematics, course taking, attitudes toward mathematics or overall background. Moreover, they argue that the observed sex difference in SAT-M, particularly of the highest levels of performance above 700, is in place before students enter adolescence.

Parsimonious evaluation of the literature and data on sex difference in mathematics at this point in time does not permit an interpretation that the observed difference between females and males in mathematics is directly related to neurological factors. The neurological substrates of mathematical performance are not at all clear. For example, it is highly inappropriate to attempt to draw relationships between reports of discalcula in patients with neurological insult, on the one hand to the academic performance of highly talented individuals in mathematics, on the other hand. More precise definitions of cognitive and neural substrates of mathematics are required before a neuropsychological interpretation of sex difference in mathematics is warranted. Nevertheless, neurodevelopmental substrates relating gender difference in mathematics may eventually emerge. It may be that existing neuropsychological and neurodevelopmental evidence of sex differences in verbal and spatial abilities may be related to components of performance in mathematics in ways that are not yet apparent. For example, Kraft (1984) assessed familial handedness in one hundred fifty-five boys and girls

between 2 1/2 and 5 1/2 years of age. She assessed performance on dichotic presentation of digits and environmental sounds and on three Wechsler subscales (vocabulary, geometric design and block design). She found sex differences in lateral specialization and spatial ability favoring boys as young as 2 1/2 years of age. Kraft interpreted her data to suggest a transition in cortical organization from subcortical to cortical structures including the corpus callosum at about four years of age with developmental differences between boys and girls.

General female/male behavioral characteristics may be better understood in light of these data. The extreme case of high in utero levels of testosterone may lead to several subtle pathologies in brain structure and immune regulation. However, a continuum may again be suggested wherein the variable is levels of testosterone. As the delay in development of the left hemisphere in males continues, a higher degree of lateralization of function results. Seemingly, the greater the delay (higher levels of testosterone), the greater the likelihood for a dominant visuo-spatial function. The more within normal ranges the levels of testosterone remain, the more likely normal male development may occur. For the female as well, circulating androgens at some level are part of the fetal environment and variability of intensity may result in the development of lateralization of function according to the same continuum suggested earlier.

Conclusion

In conclusion, an appropriate understanding of sex differences in neuropsychological and cognitive function requires a model of individual difference that permits consideration of the dynamic interaction of a cluster of

key variables. These variables comprise a broad profile adequate to explain the individual differences in characteristic cognitive and learning style pattern (Languis, 1983a, Languis and Kraft, 1984). Languis (1981) defined learning style as the consistent pattern of behavior and performance by which an individual approaches educational experiences. It is formed in the deep structure of neural organization and personality which molds and is molded by human development variables and cultural influences of experience in the home, school and society. An individual's learning style is consistent with the general expectation that the individual brings to an experience and the strategies by which he or she constructs personal meaning from the experience.

Individuals develop and exhibit a learning style rather early in life. Structure, originally laid down through inheritance, is influenced prenatally as we have seen. That with which one is born provides a predisposition toward a consistent learning pattern, but it is only the beginning. Development and change continues through the individual's encounters with the environment. Learning style therefore needs to be conceptualized in terms of deeply embedded structures within the individual. This definition of learning style suggests that we will not make lasting contributions to educational practice by diagnosing learning styles solely on the basis of self report measures of students' preferences. The definition also suggests that learning style is a reflection of basic and deeply embedded structures that comprise individual differences.

As such the individual's learning style is rather stable but is not fixed. First, any individual's world view is broad enough to allow the individual to adapt somewhat to the conditions of a particular learning situation. There is some range of accommodation within each individual's learning style. But the nature of that adaptive range will vary among individuals. Moreover, the manner

by which each individual adjusts will be unique to him or her. Therefore we need to look beyond surface features and behaviors to understand the learning processes an individual employs in adapting his/her learning style to cope with educational tasks (Languis, 1983c). Consideration of a vector model of gender difference may be useful in conceptualizing the necessary breadth and complexity of human sex differences and to provide directions for research, development and application to practice in the helping professions (Languis, Naour, Martin and Buffer, 1984).

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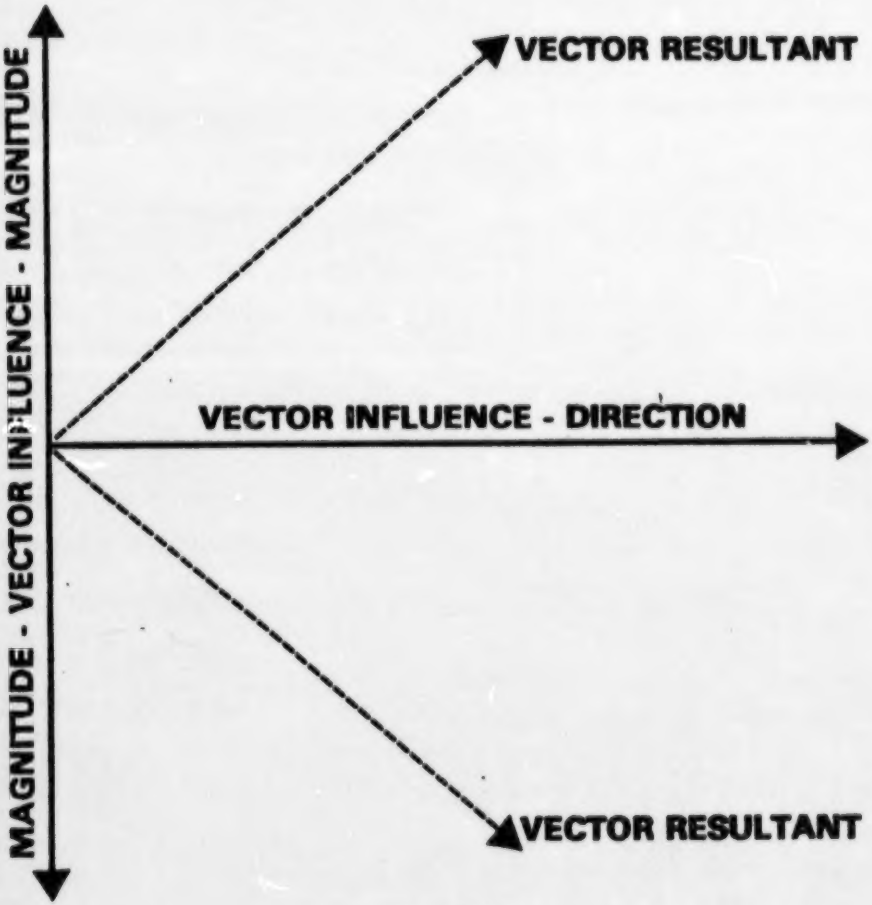
VECTOR RESULTANT
MAGNITUDE - VECTOR INFLUENCE - MAGNITUDE
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VECTOR RESULTANT

Figure 1

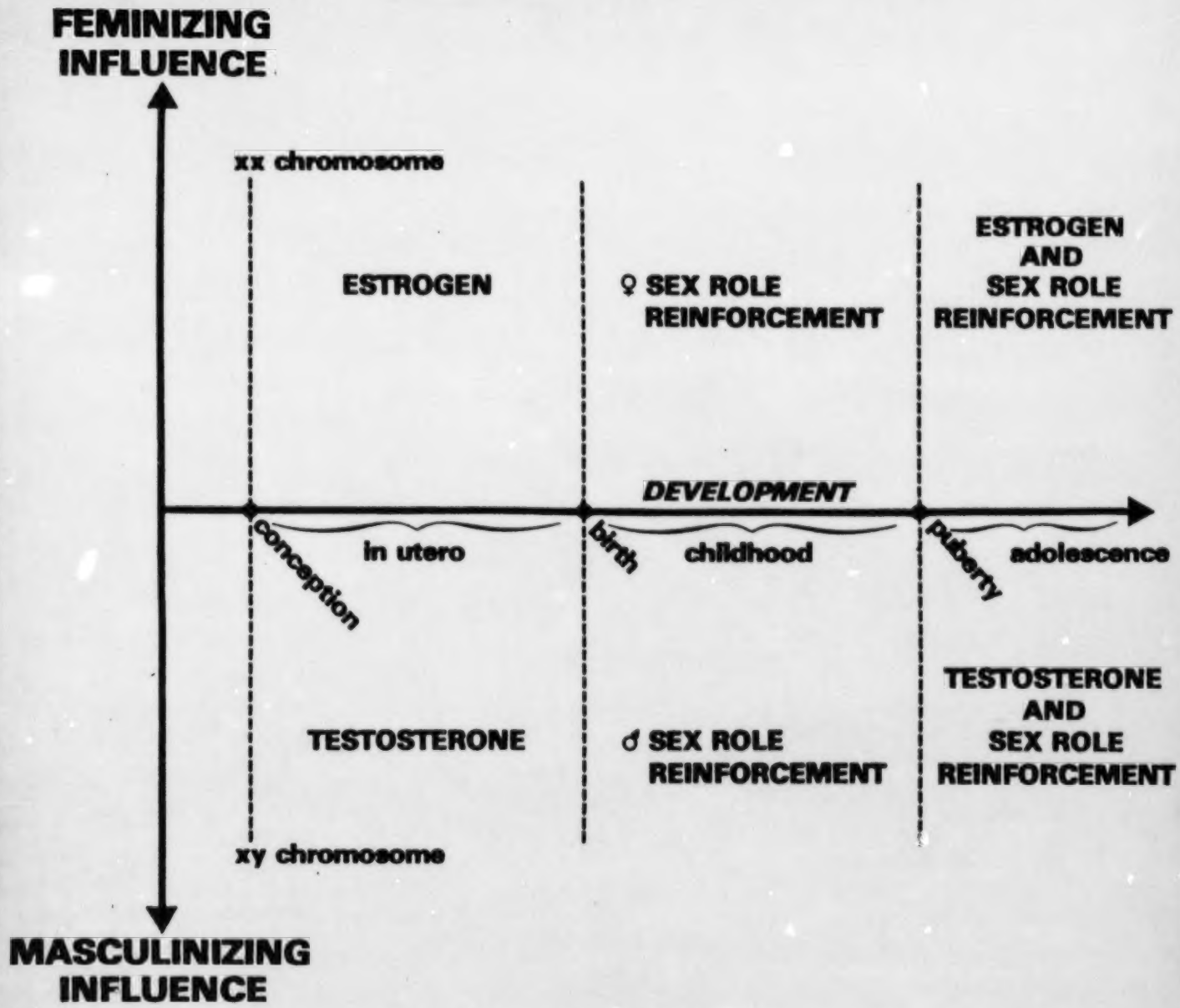
FEMINIZING INFLUENCE
xx chromosome
ESTROGEN
♀ SEX ROLE REINFORCEMENT
ESTROGEN AND SEX ROLE REINFORCEMENT
DEVELOPMENT
conception
in utero
birth
childhood
puberty
adolescence
TESTOSTERONE
♂ SEX ROLE REINFORCEMENT
TESTOSTERONE AND SEX ROLE REINFORCEMENT
xy chromosome
MASCULINIZING INFLUENCE

Figure 2

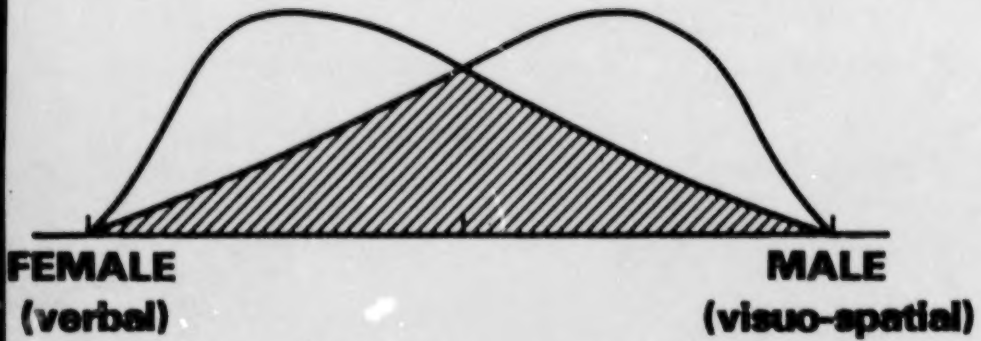

Figure 3

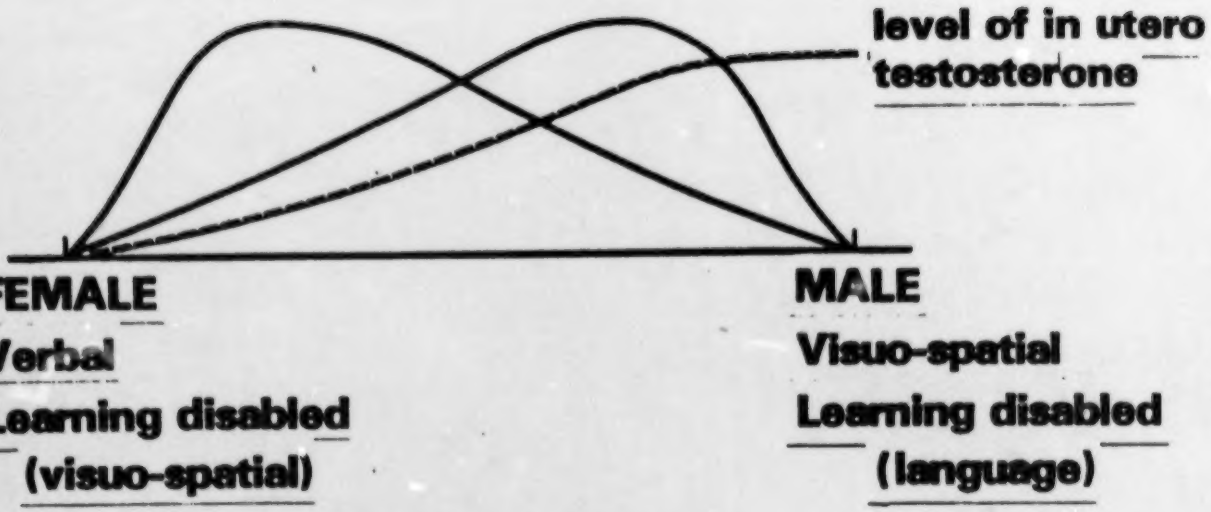
level of in utero
testosterone
FEMALE
Verbal
Learning disabled
(visuo-spatial)
MALE
Visuo-spatial
Learning disabled
(language)

Figure 4